



Active Flow Control Enhanced Aileron of the High-Lift Common Research Model at Takeoff Condition

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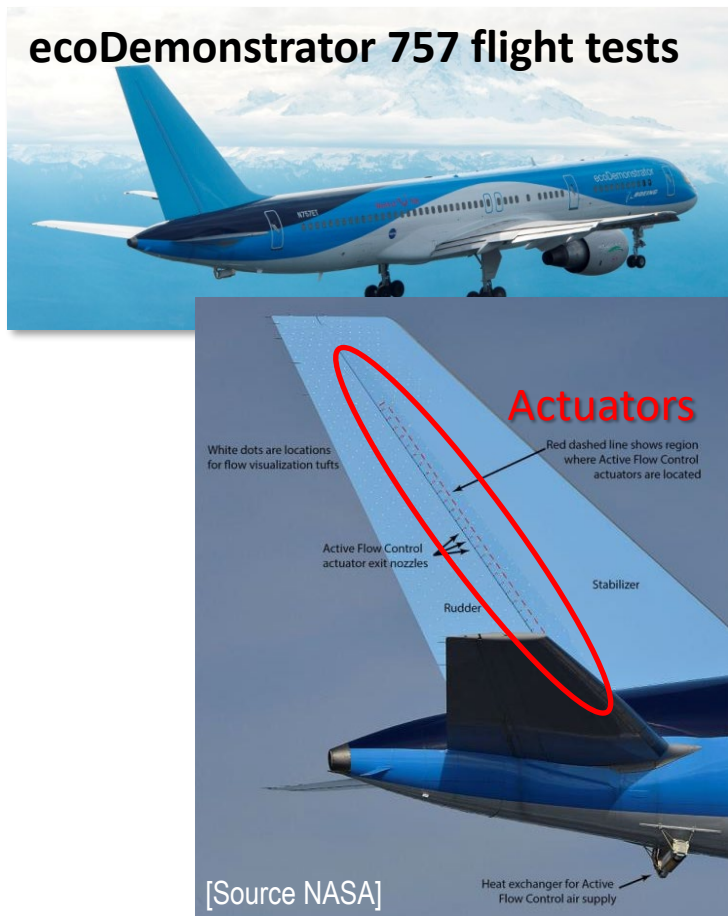
AIAA SciTech 2025

Background and Motivation



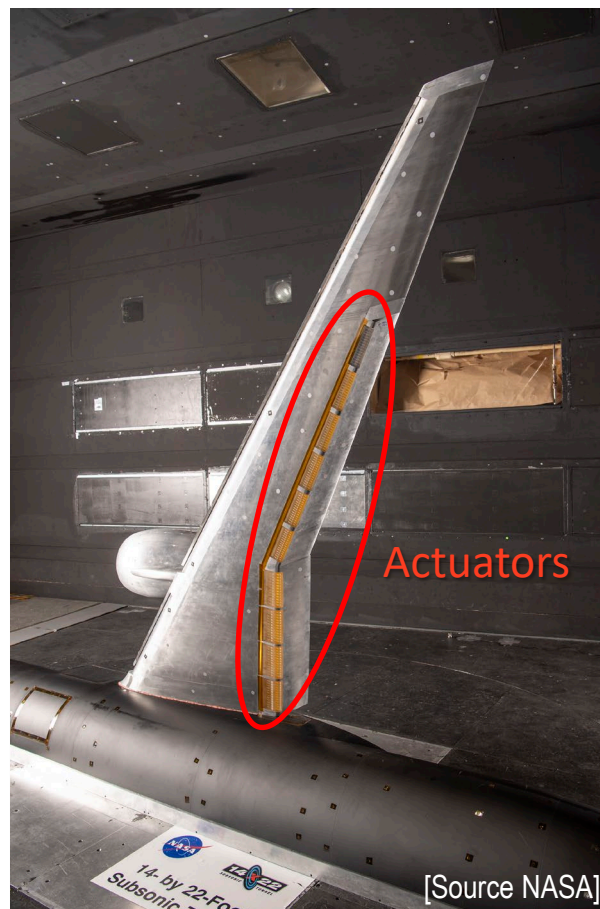
2015

ecoDemonstrator 757 flight tests



AFC-Enhanced Vertical Tail
Reduce weight, drag and rate of fuel burn

2018



Simplified High-Lift
Reduce Cruise Drag

2024

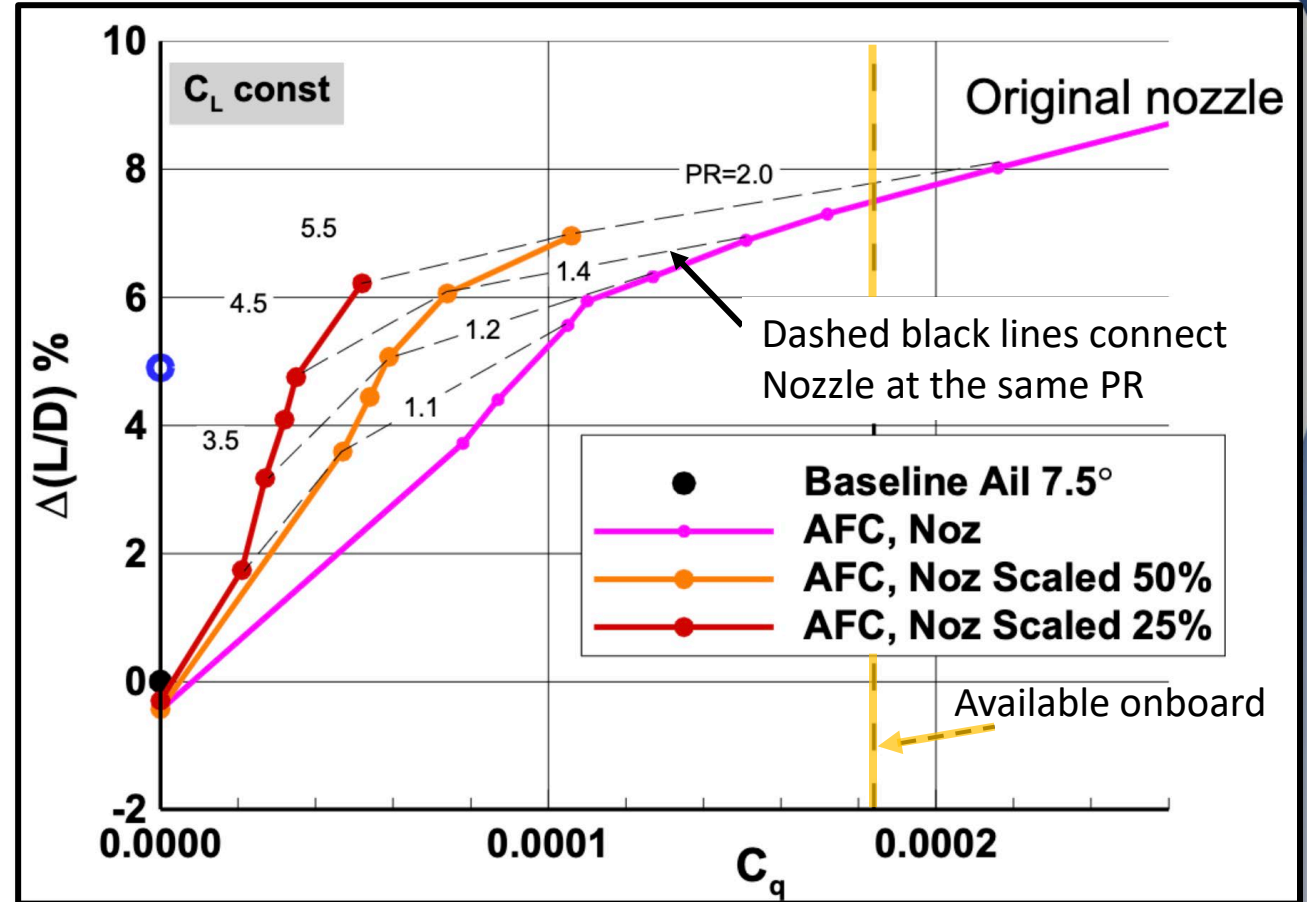


AFC-Enhanced Aileron
Increase L/D

Motivation



- 1% Improvement in L/D for a large, generic twin engine transport is equivalent to
 - 2800 lb increase in payload or
 - 150 nm increase in range
 - Garner et al., AIAA Paper 1991-1527, doi.org/10.2514/6.1991-1527



Shmilovich et al., AIAA Paper 2023-0655,
doi.org/10.2514/6.2023-0655

CRM-HL Model: Takeoff Configuration



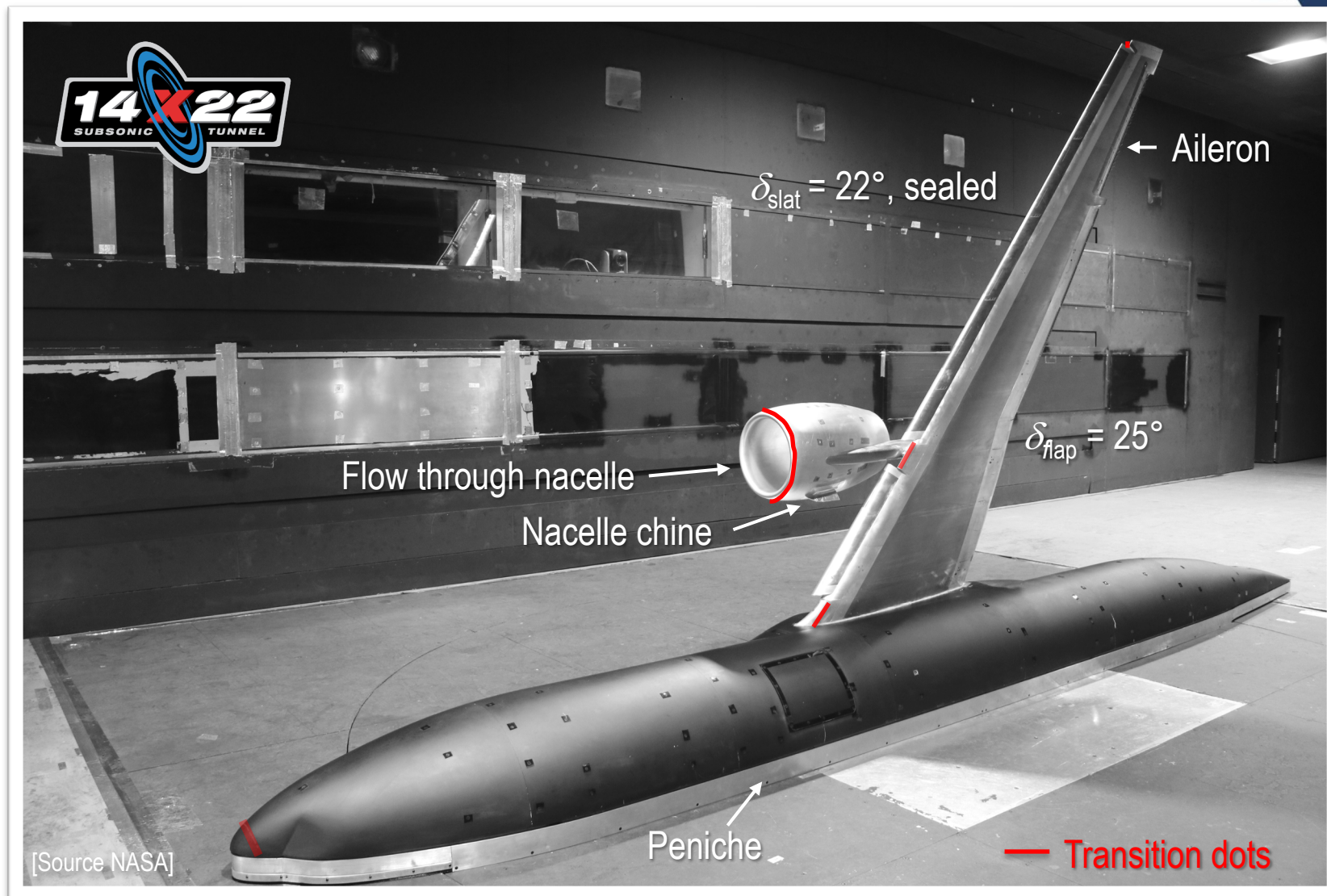
AFC Angle of attack range

Reynolds number

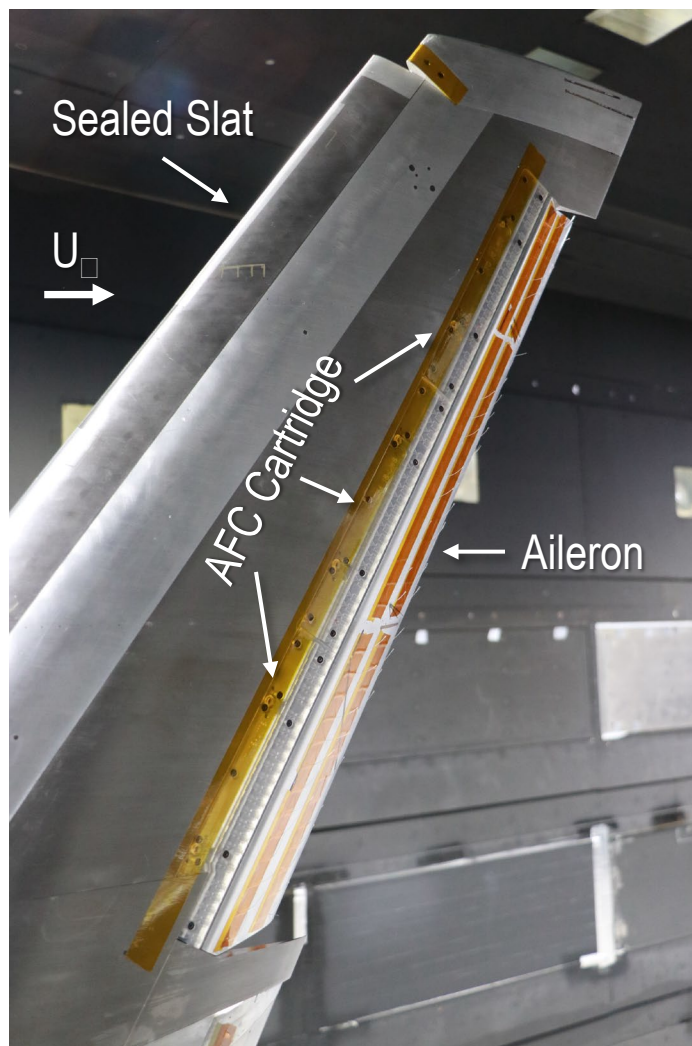
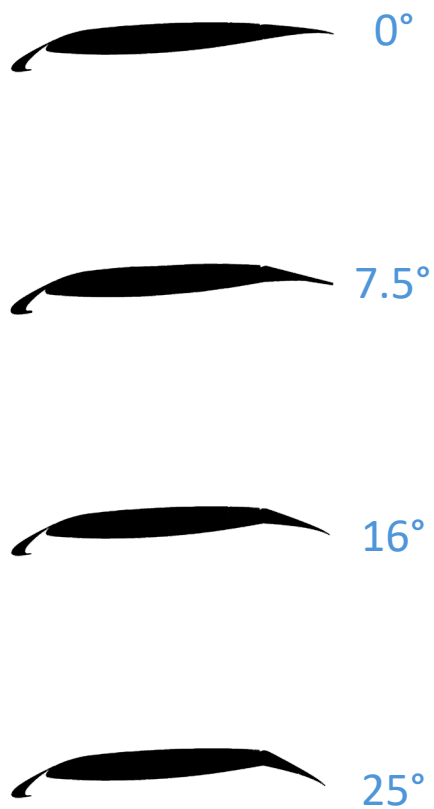
Mach number

Sealed Slat

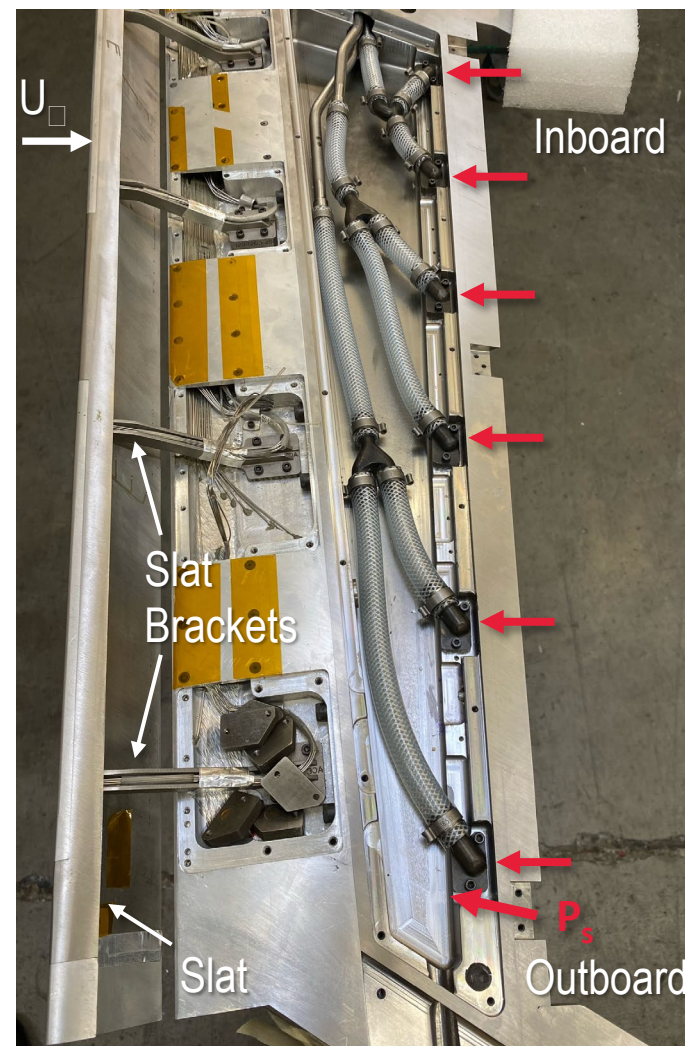
Inboard and Outboard flap



CRM-HL Model: Aileron



Upper Surface

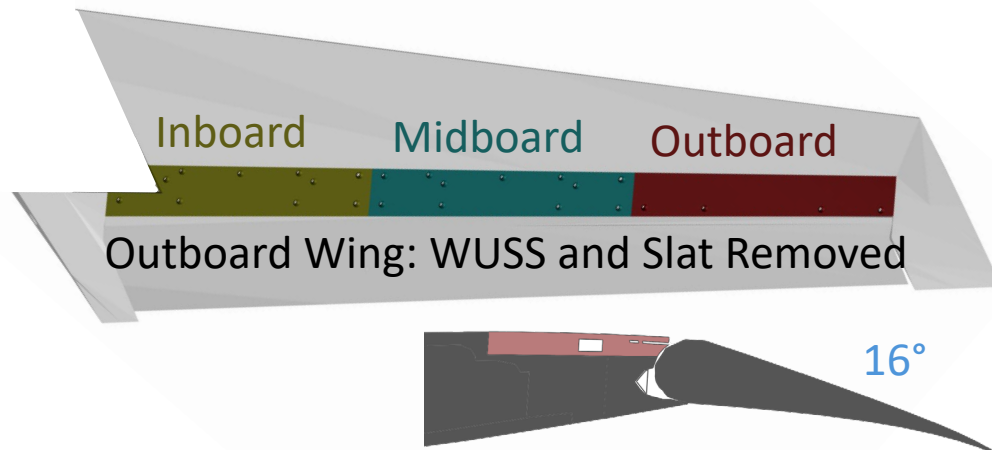


Lower Surface

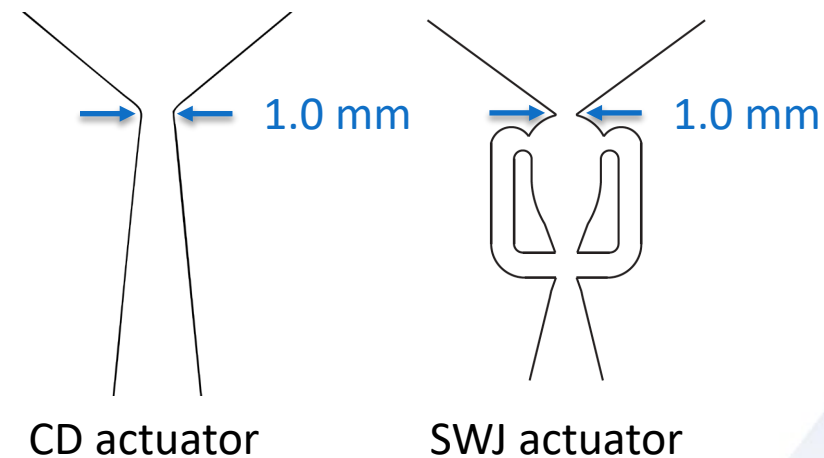
AFC Actuators Spacing

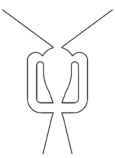


Type		Inboard Qty	Midboard Qty	Outboard Qty	Total nozzle area, mm ²
Sweeping Jet (SWJ)	SWJ1	23	23	23	43
	SWJ2	12	11	12	22
	SWJ3	6	6	6	12
Convergent Divergent Jet (CD)	CD1	23	23	23	43
	CD2	12	11	12	22



All actuator nozzle exits were 0.5 mm H x 1.0 mm W





Sweeping Jets: Lift Coefficient



Amplitude
increase

SWJ1, NPR=3

SWJ1, NPR=2

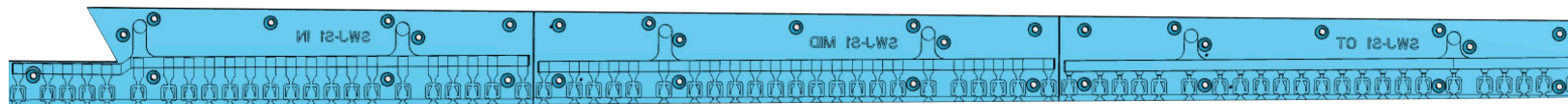
SWJ2, NPR=3

SWJ2, NPR=2

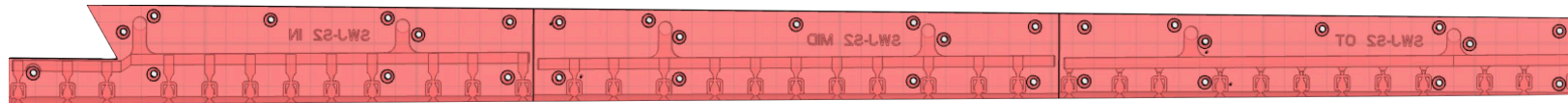
SWJ3, NPR=3

NPR=1, $\delta_a = 16^\circ$

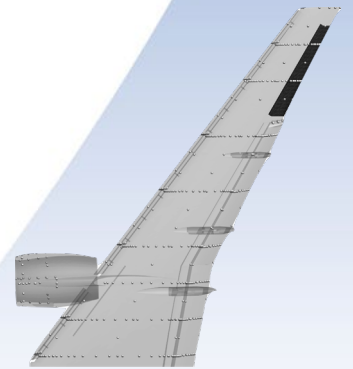
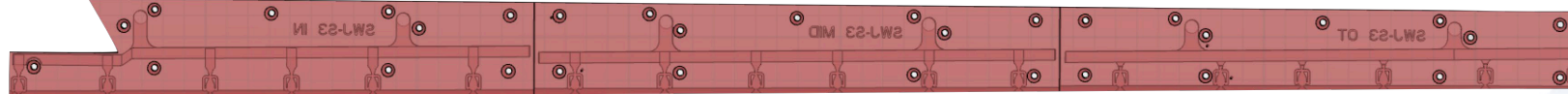
SWJ1

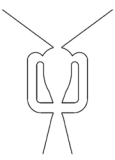


SWJ2



SWJ3





Sweeping Jets: Drag Coefficient



Amplitude
increase



← NPR=1, $\delta_a = 16^\circ$

← SWJ3, NPR=3

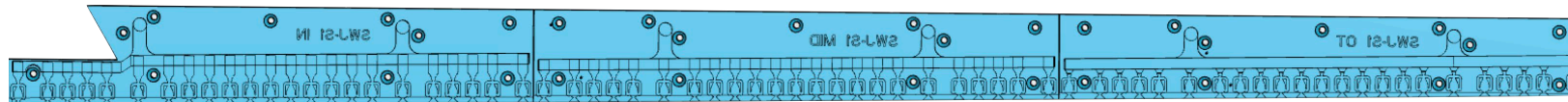
← SWJ2, NPR=2

← SWJ2, NPR=3

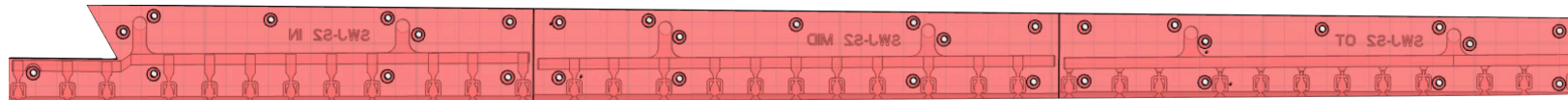
← SWJ1, NPR=2

← SWJ1, NPR=3

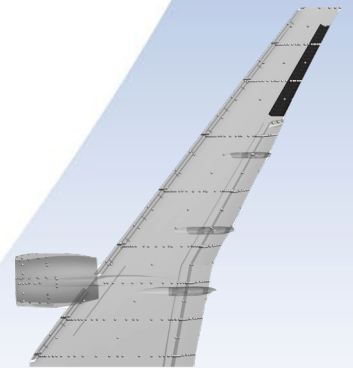
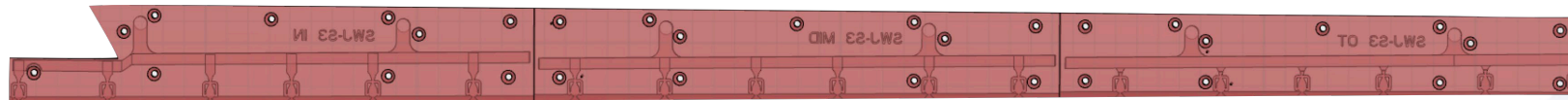
SWJ1

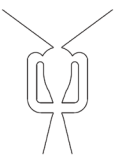


SWJ2



SWJ3





Sweeping Jets: Lift-to-Drag ratio



SWJ1, NPR=3

SWJ1, NPR=2

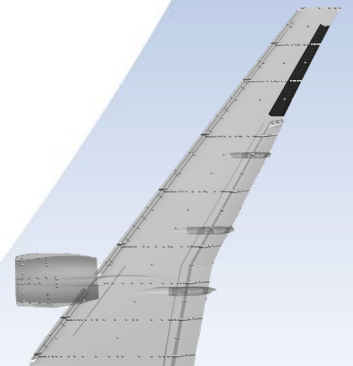
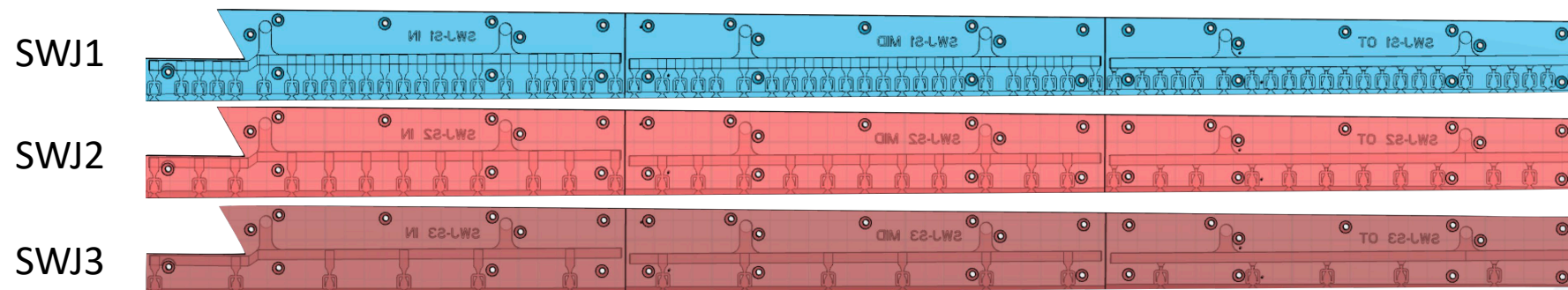
SWJ2, NPR=3

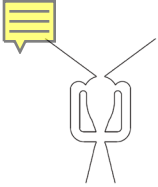
SWJ2, NPR=2

SWJ3, NPR=3

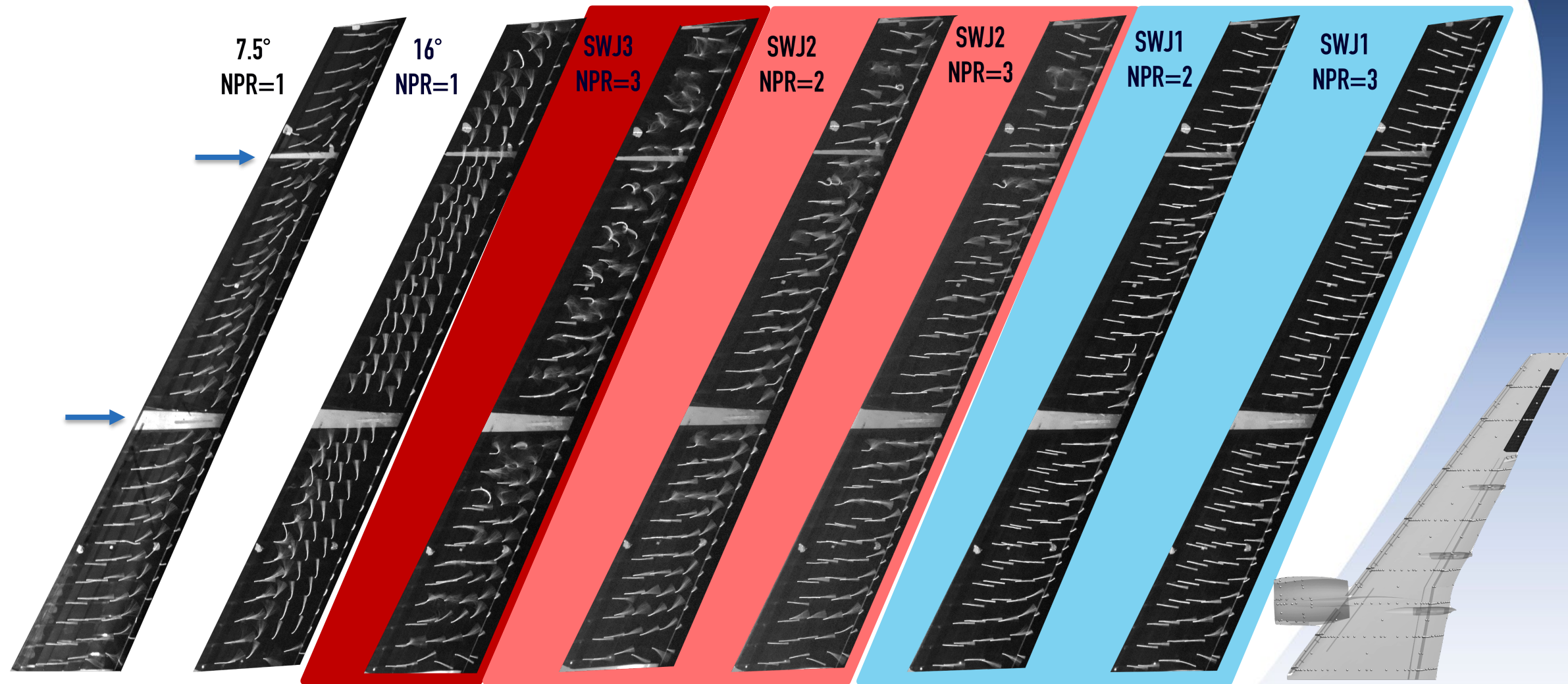
NPR=1, $\delta_a = 16^\circ$

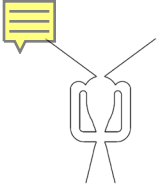
Amplitude
increase



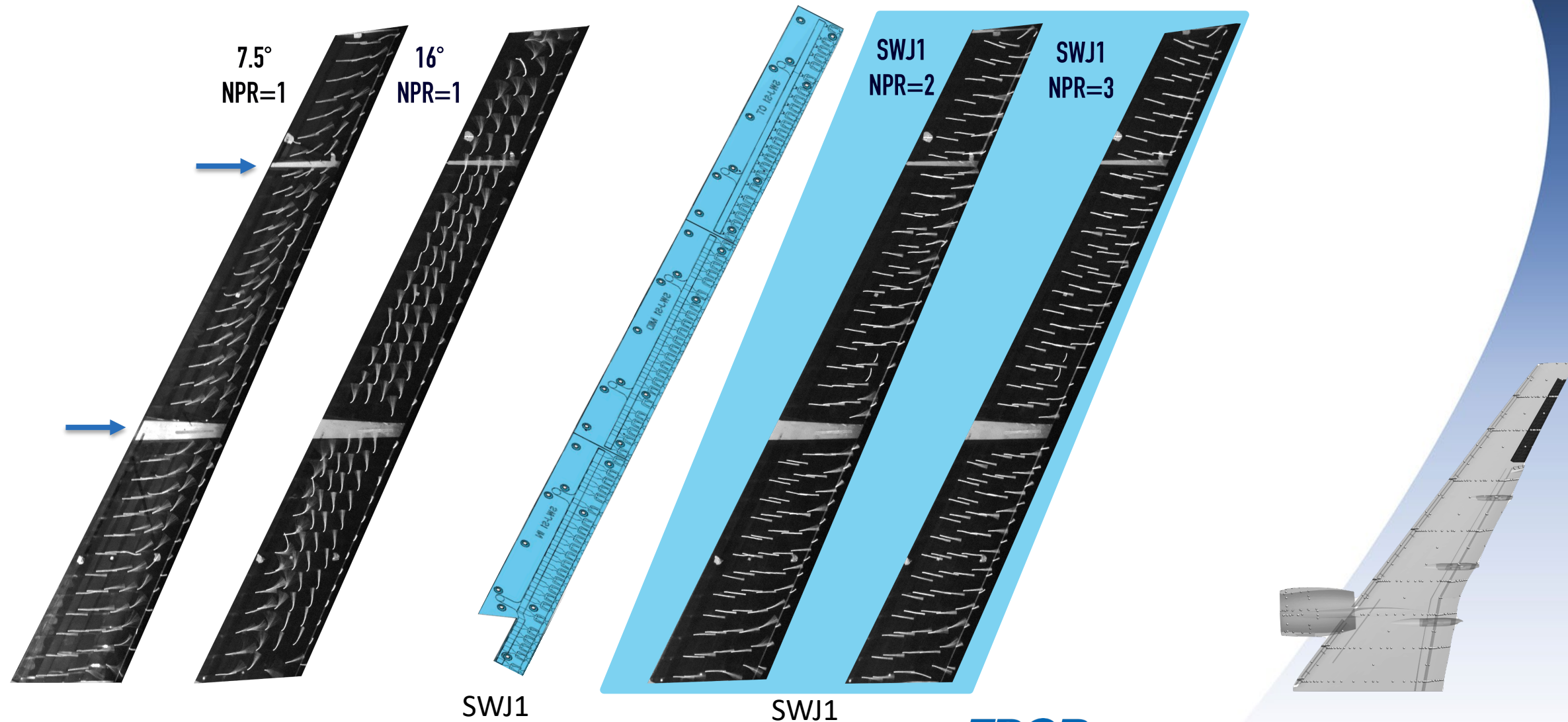


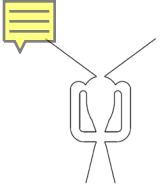
Sweeping Jets: Amplitude scan at 16°



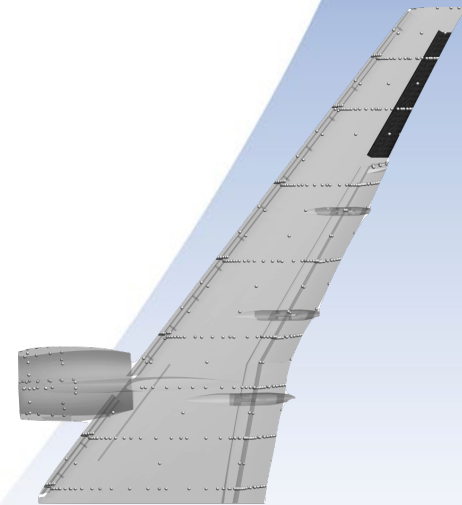
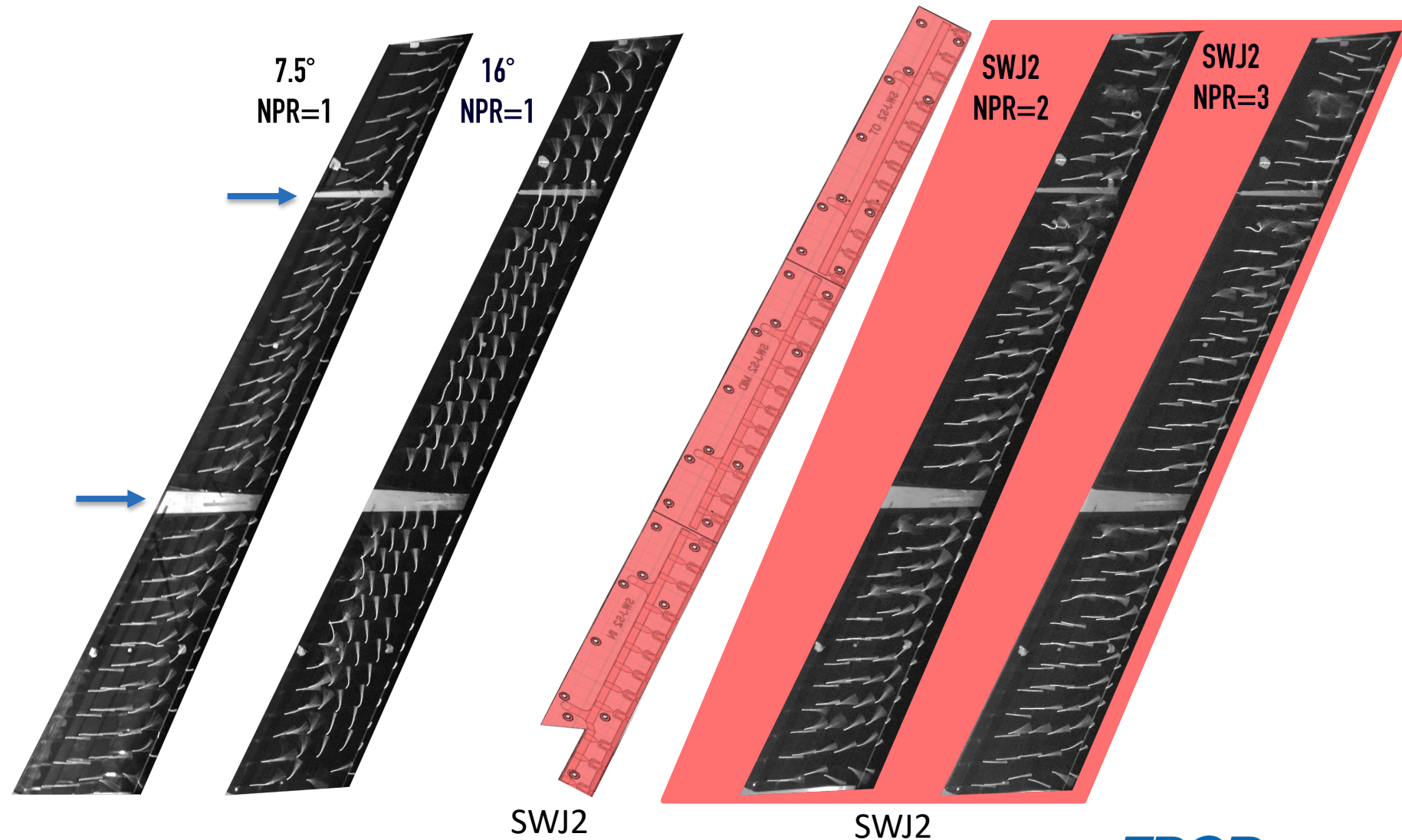


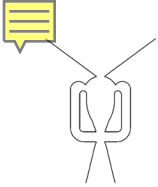
Sweeping Jets: Amplitude scan at 16°



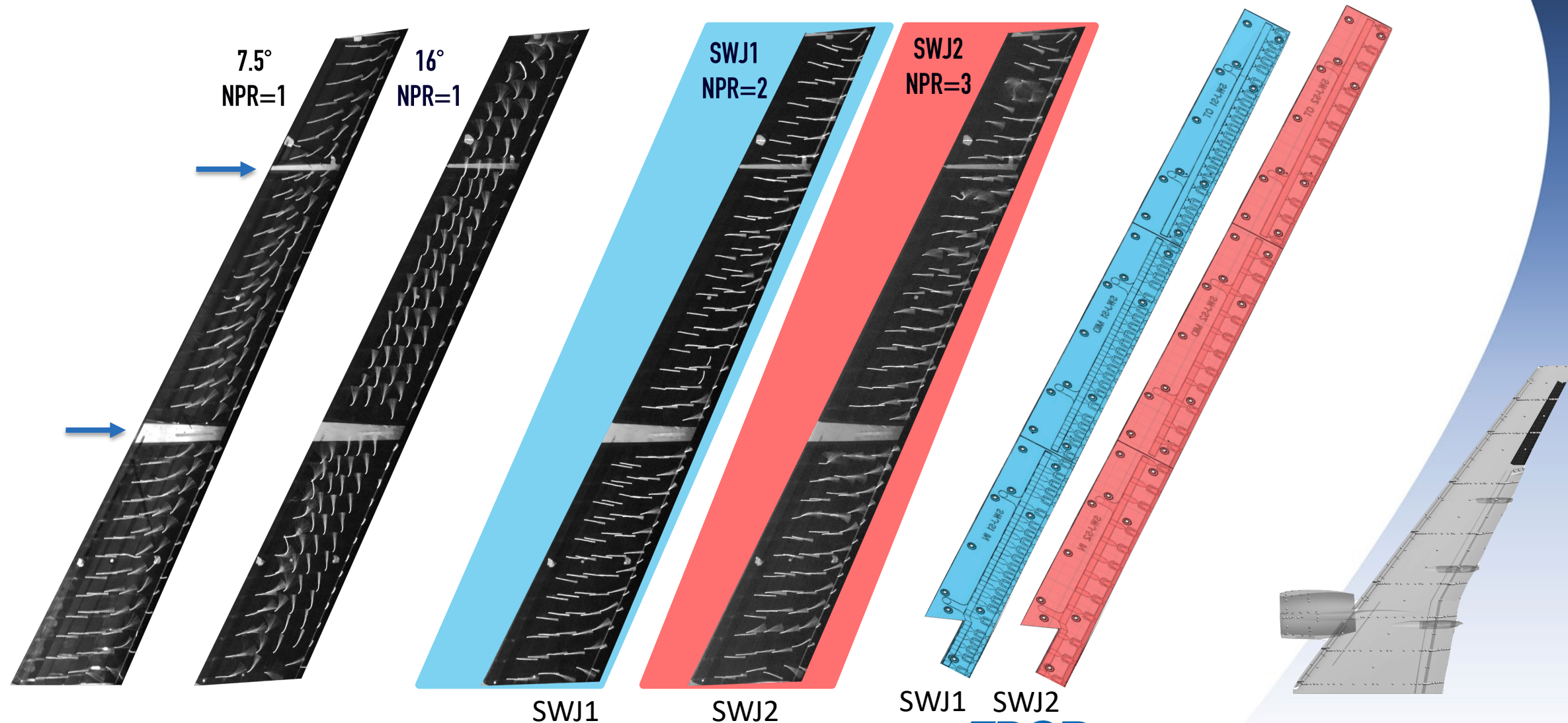


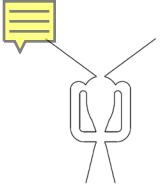
Sweeping Jets: Amplitude scan at 16°



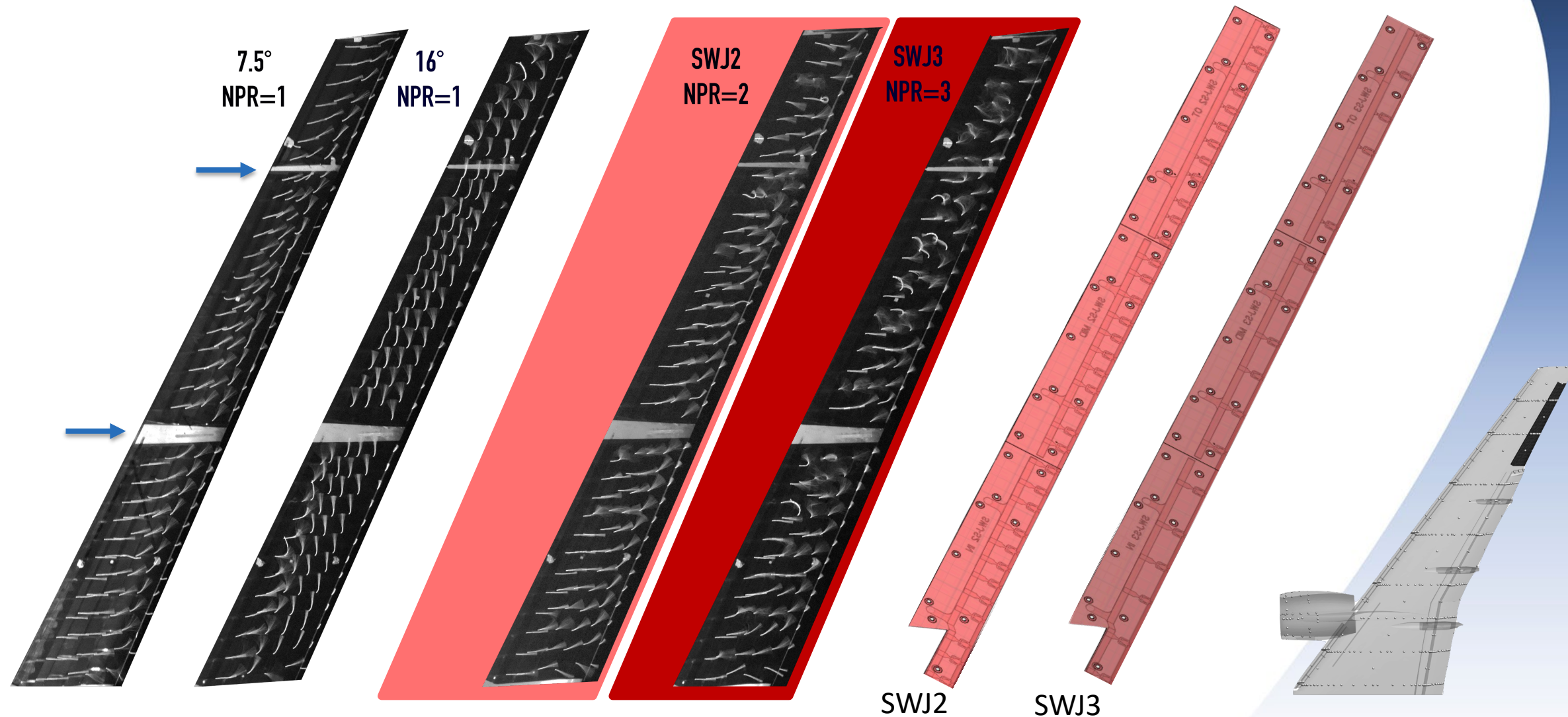


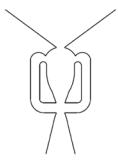
Sweeping Jets: Amplitude scan at 16°



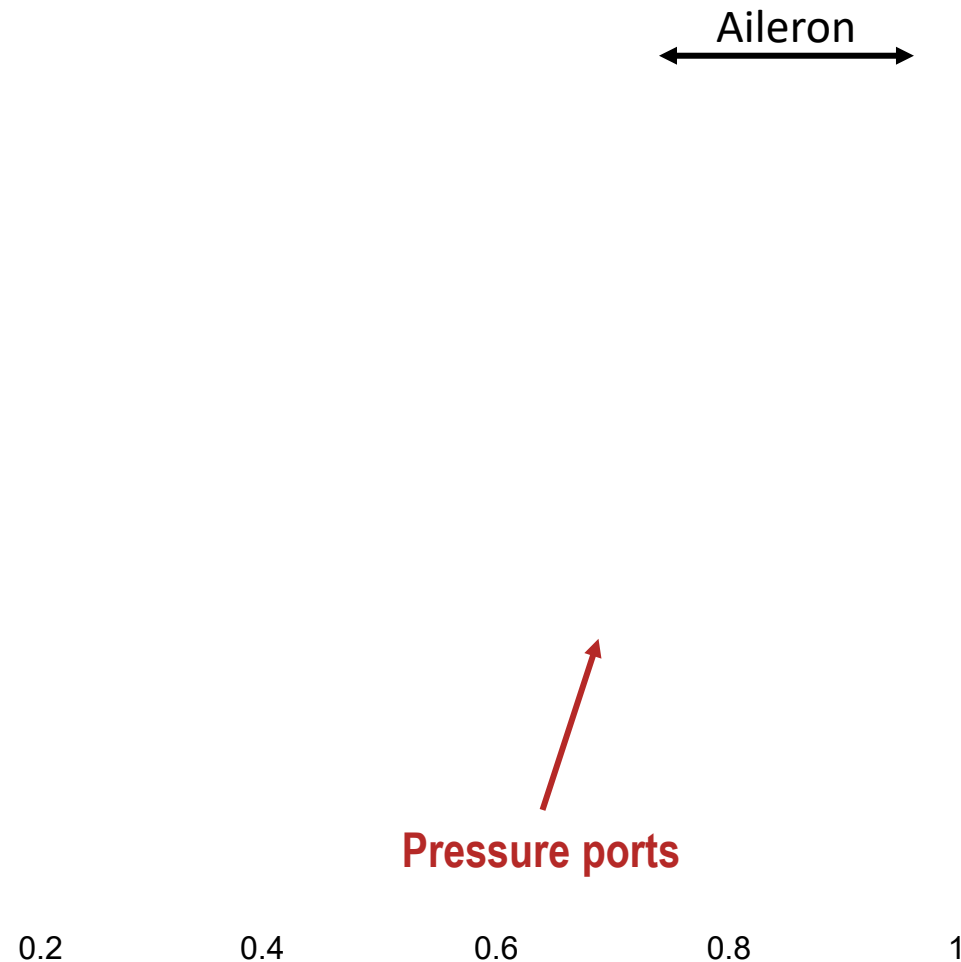


Sweeping Jets: Amplitude scan at 16°

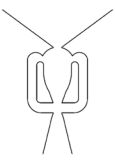




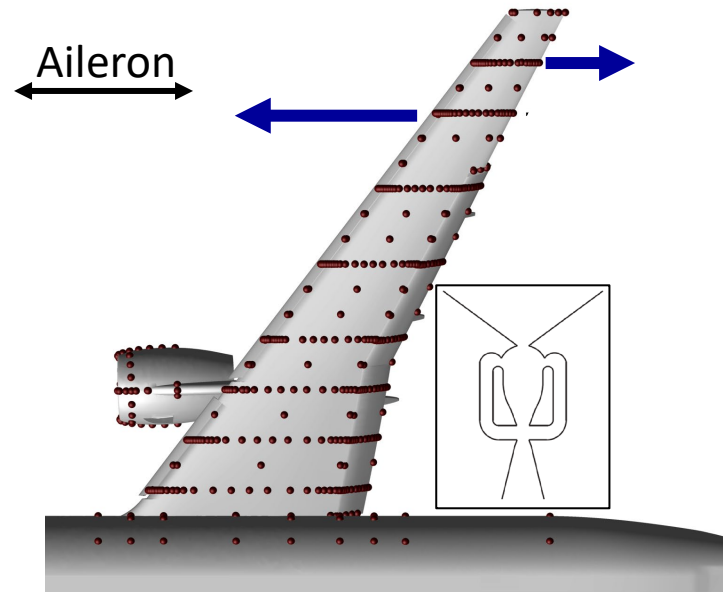
Sweeping Jets: Spanwise C_p Distributions



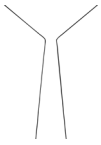
- Increased suction pressure upstream of the aileron section
- Suction pressure increases with actuation amplitude
- AFC effects are noticeable inboard of the aileron
- SWJ1 at NPR=2 similar performance to SWJ2 at NPR=3



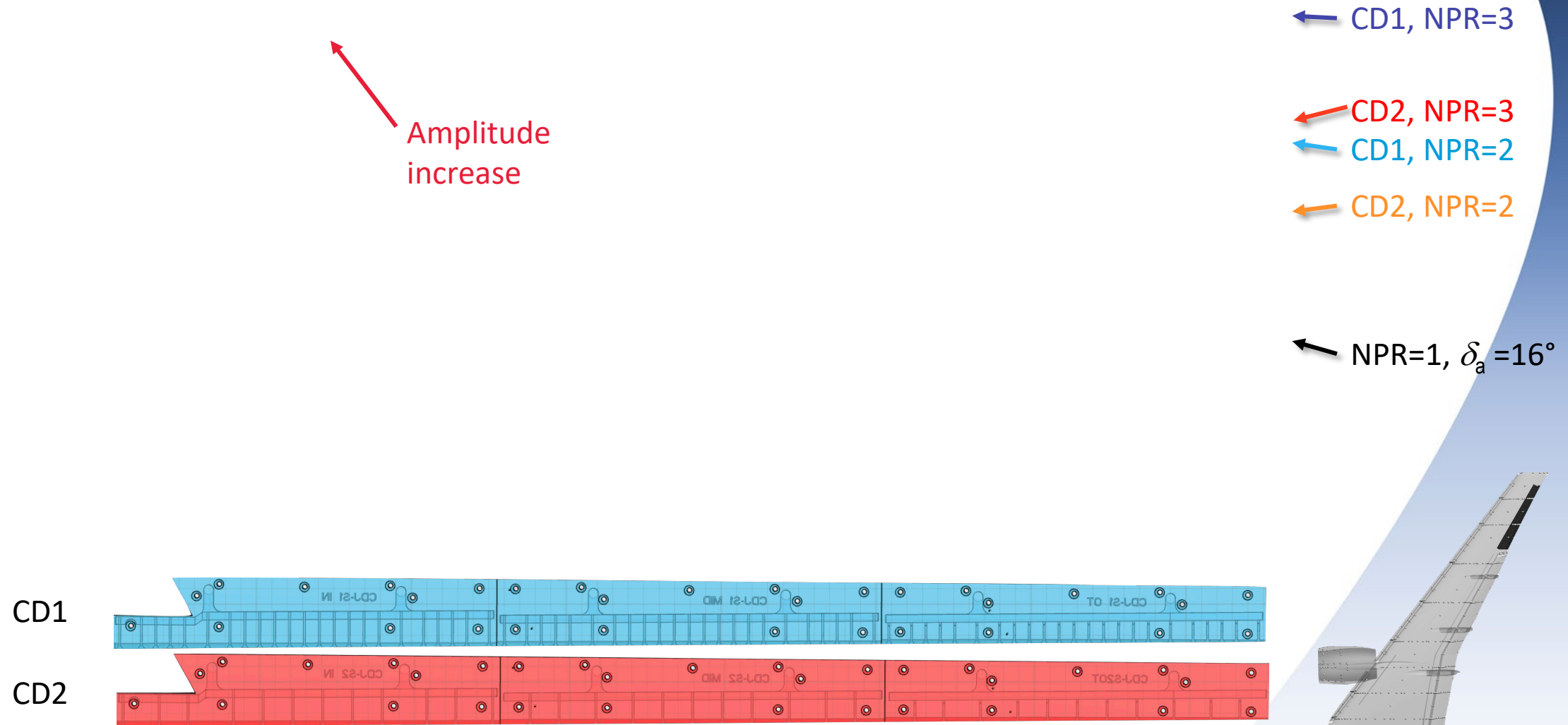
Sweeping Jets: Streamwise C_p Distributions



- NPR=1, flow separation at the aileron's TE
- AFC cases: Suction pressure increased: slat + main element
- Flow attached: SWJ1 at NPR=2 and SWJ2 at NPR=3
- C_p distribution improvements are consistent with C_L increase



CD Steady Jets: Lift Coefficient



CD Steady Jets: Drag Coefficient



Amplitude
increase



← NPR=1, $\delta_a = 16^\circ$

← CD2, NPR=2

← CD2, NPR=3

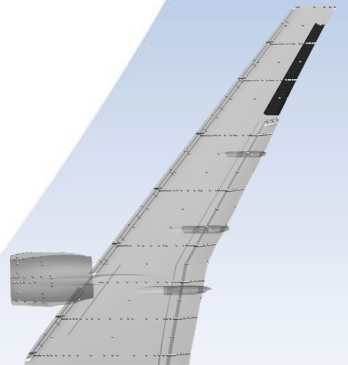
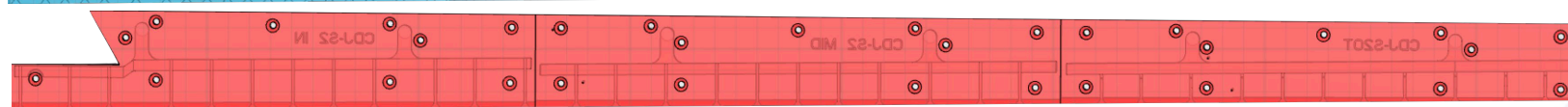
← CD1, NPR=2

← CD1, NPR=3

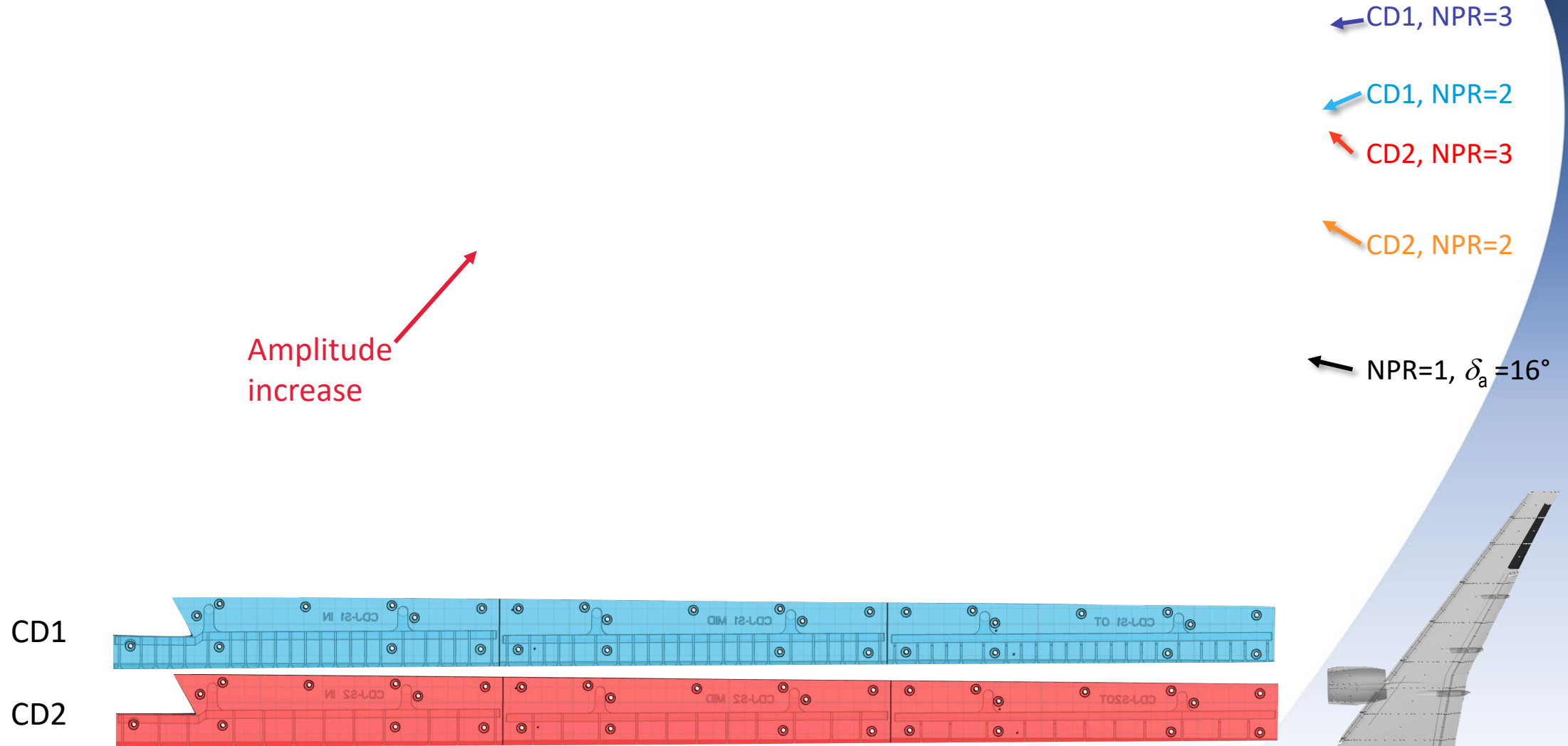
CD1

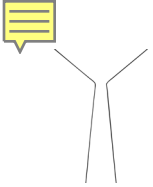


CD2

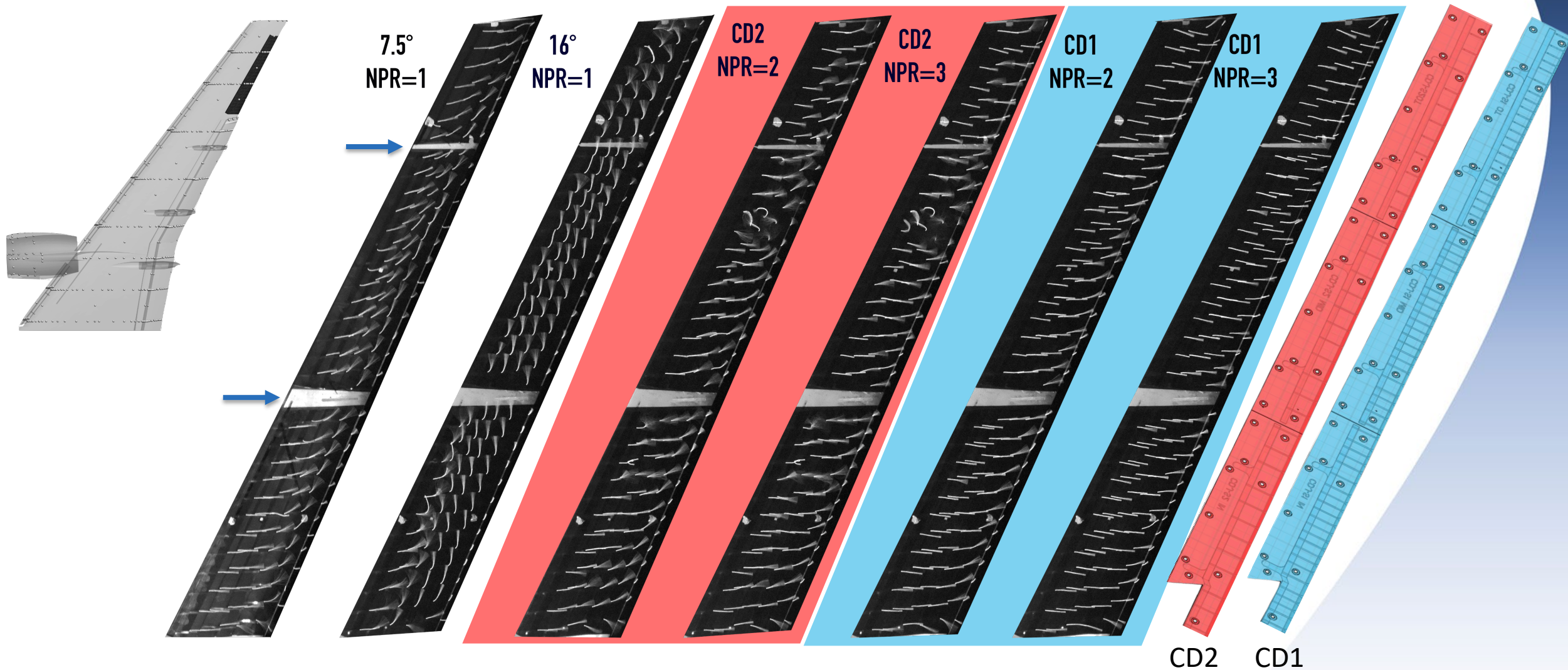


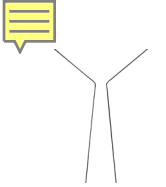
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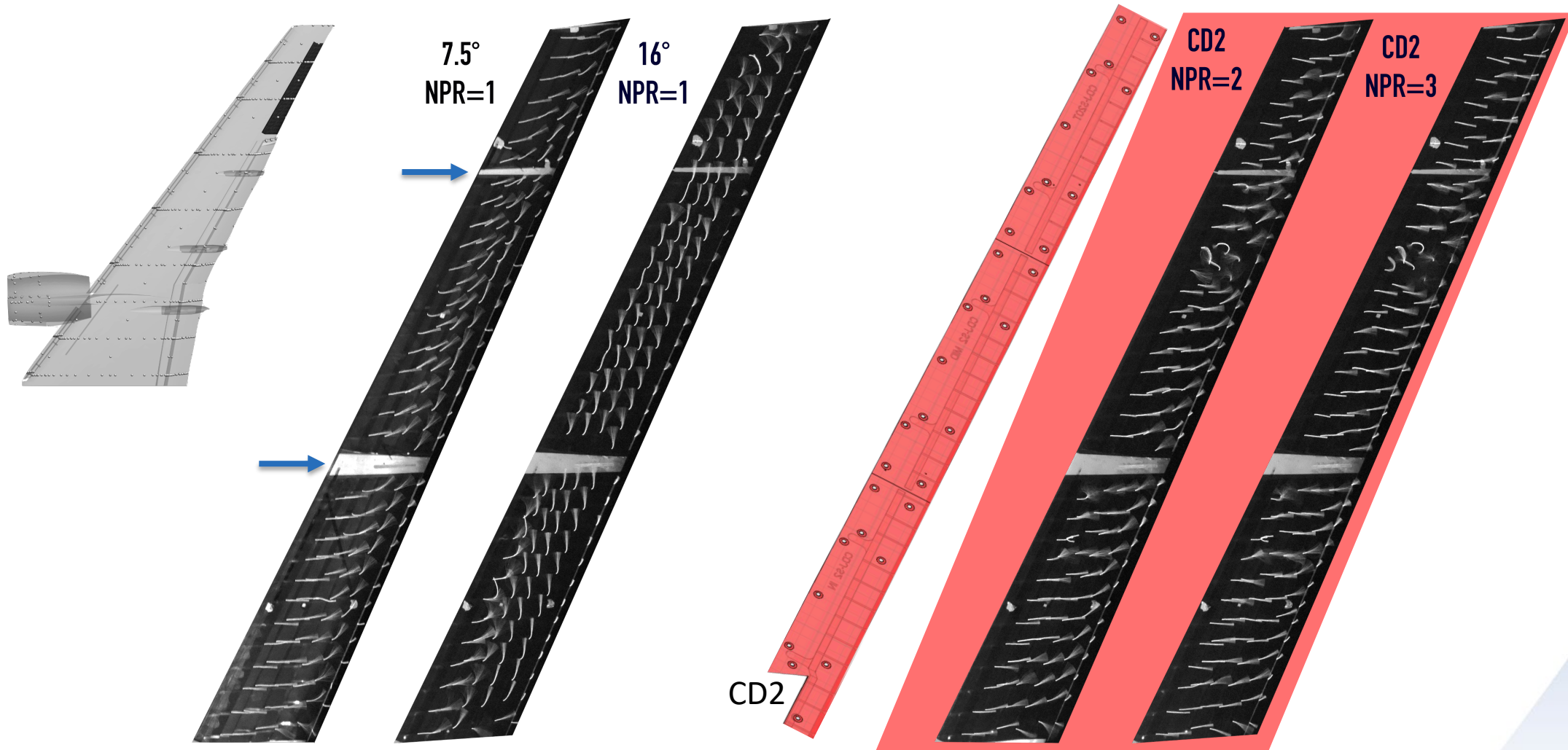


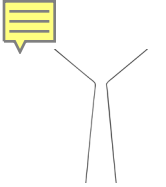
CD Steady Jets: Amplitude Scan at 16°



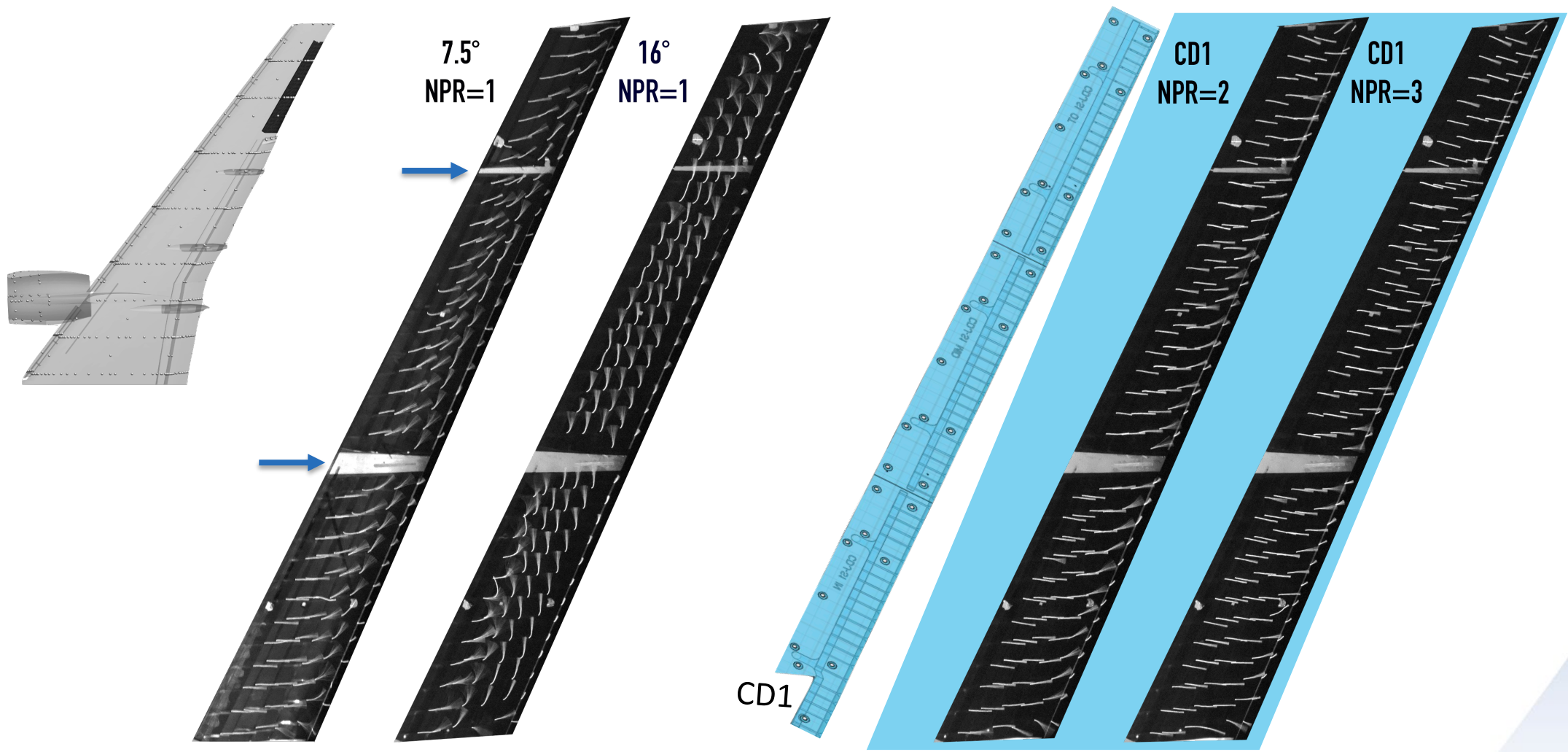


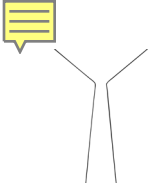
CD Steady Jets: Amplitude Scan at 16°



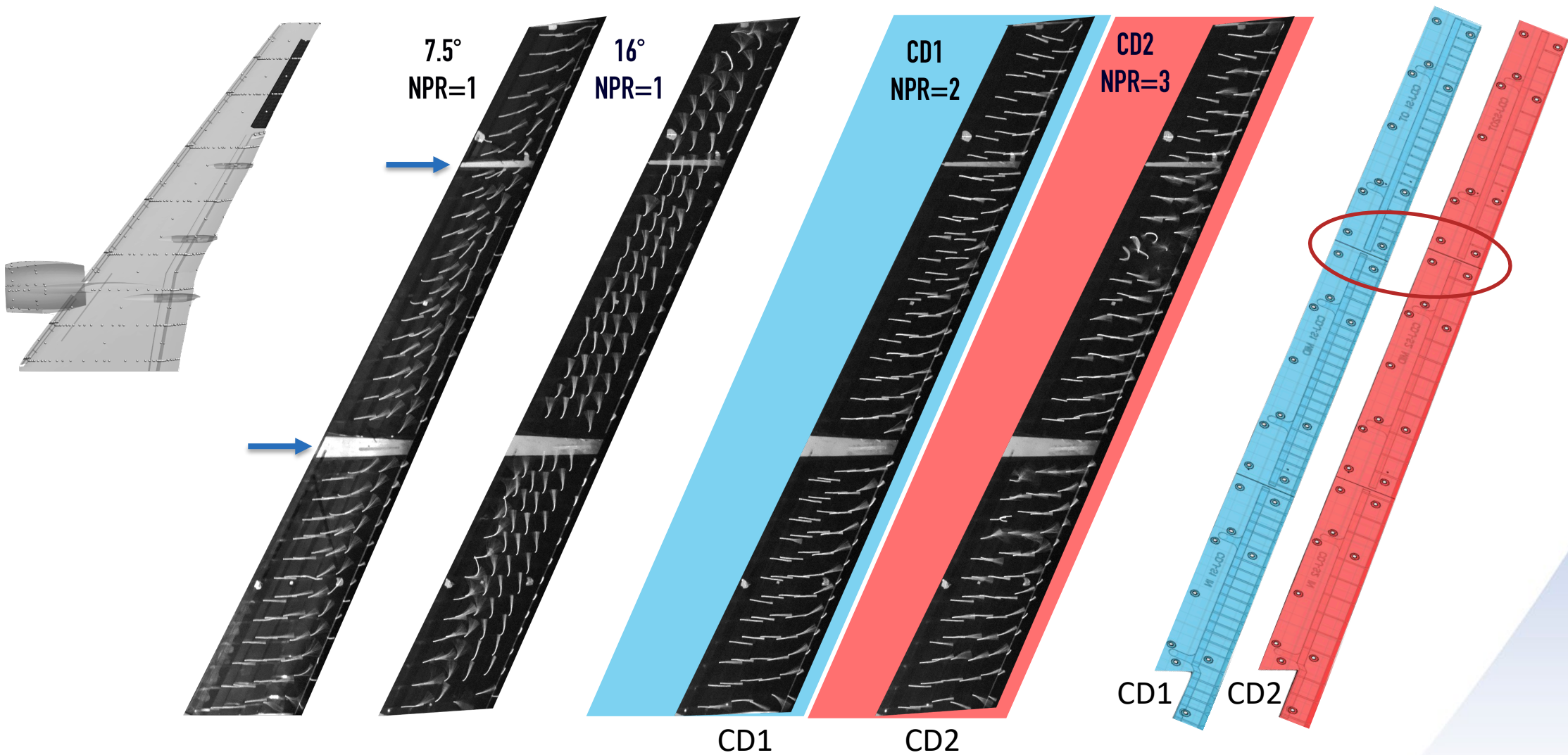


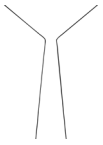
CD Steady Jets: Amplitude Scan at 16°



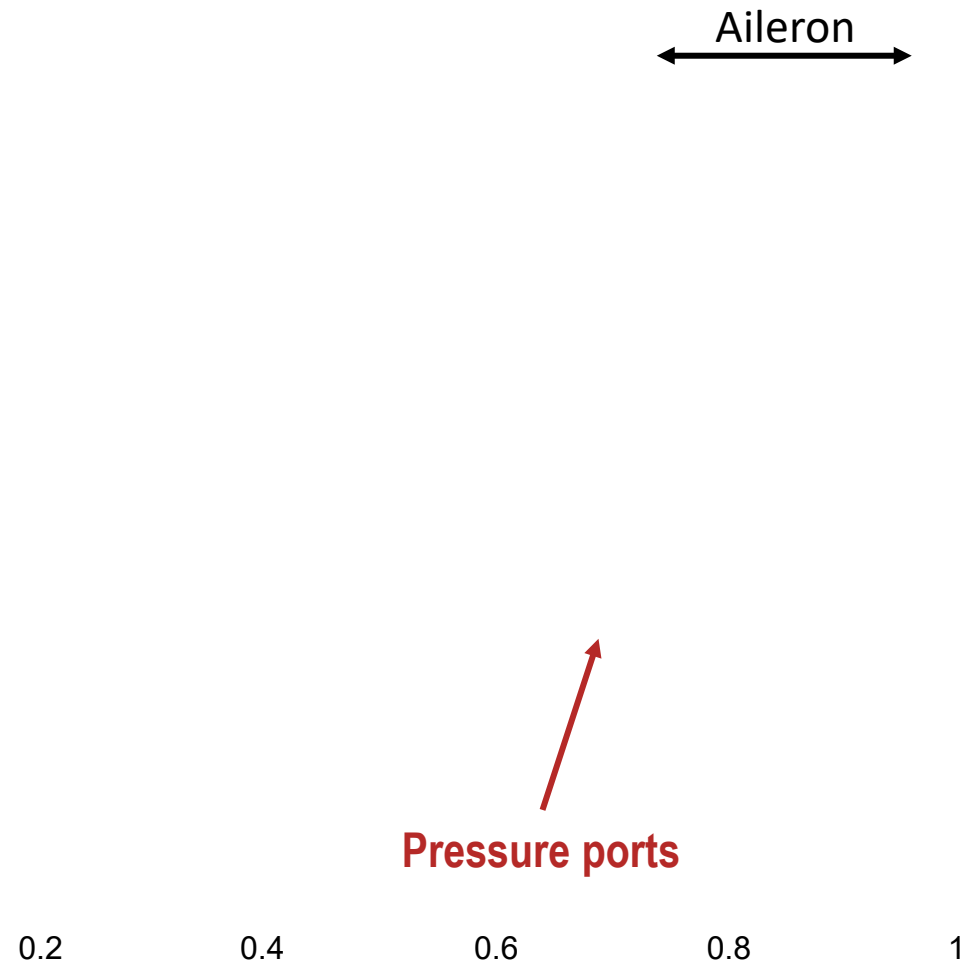


CD Steady Jets: Amplitude Scan at 16°

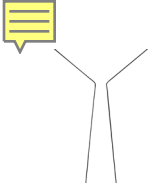




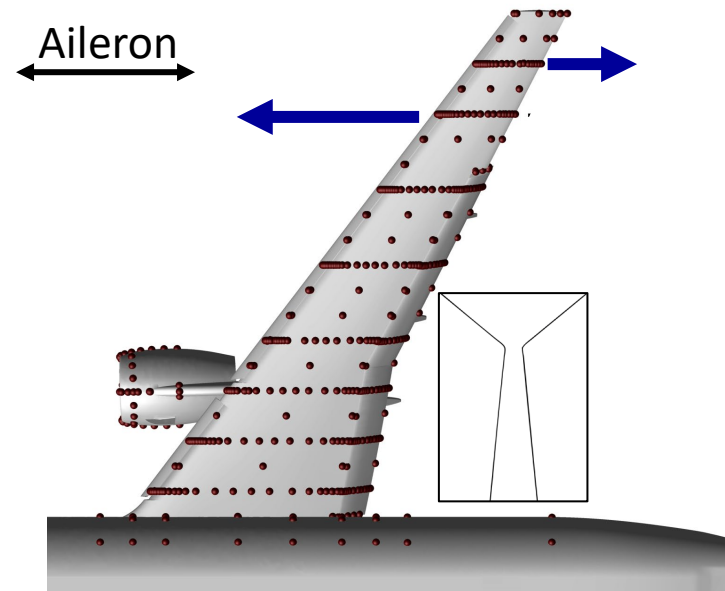
CD Steady Jets: Spanwise C_p Distributions



- Increased suction pressure upstream of the aileron section
- Suction pressure increases with actuation amplitude
- AFC effects are noticeable inboard of the aileron
- CD1 at NPR=2 similar performance to CD2 at NPR=3

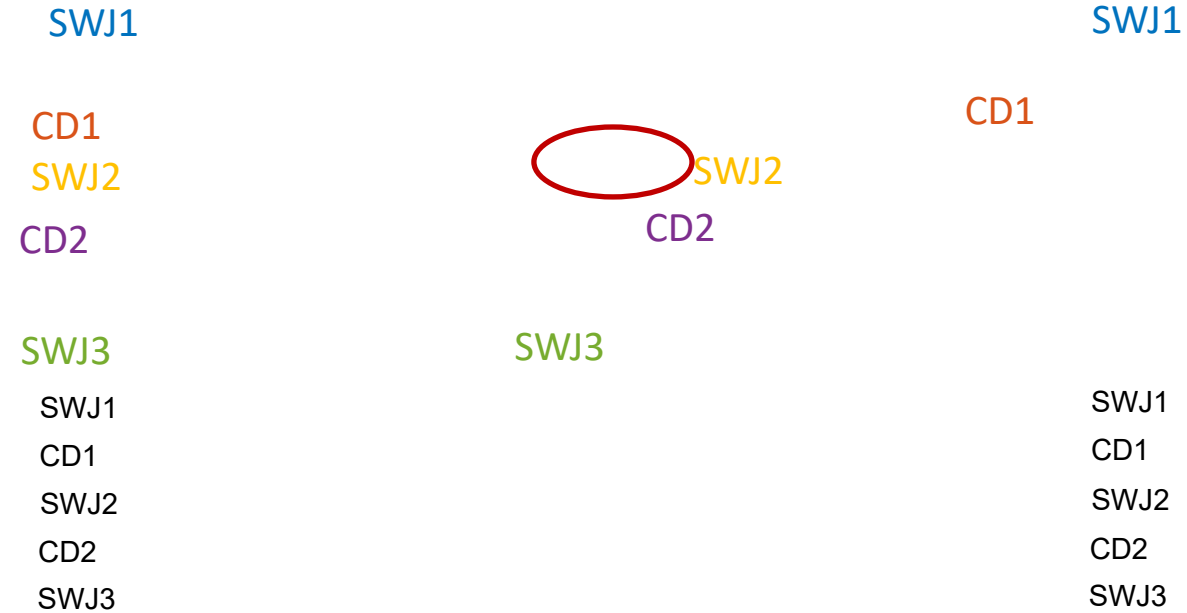


CD Steady Jets: Streamwise C_p Distributions



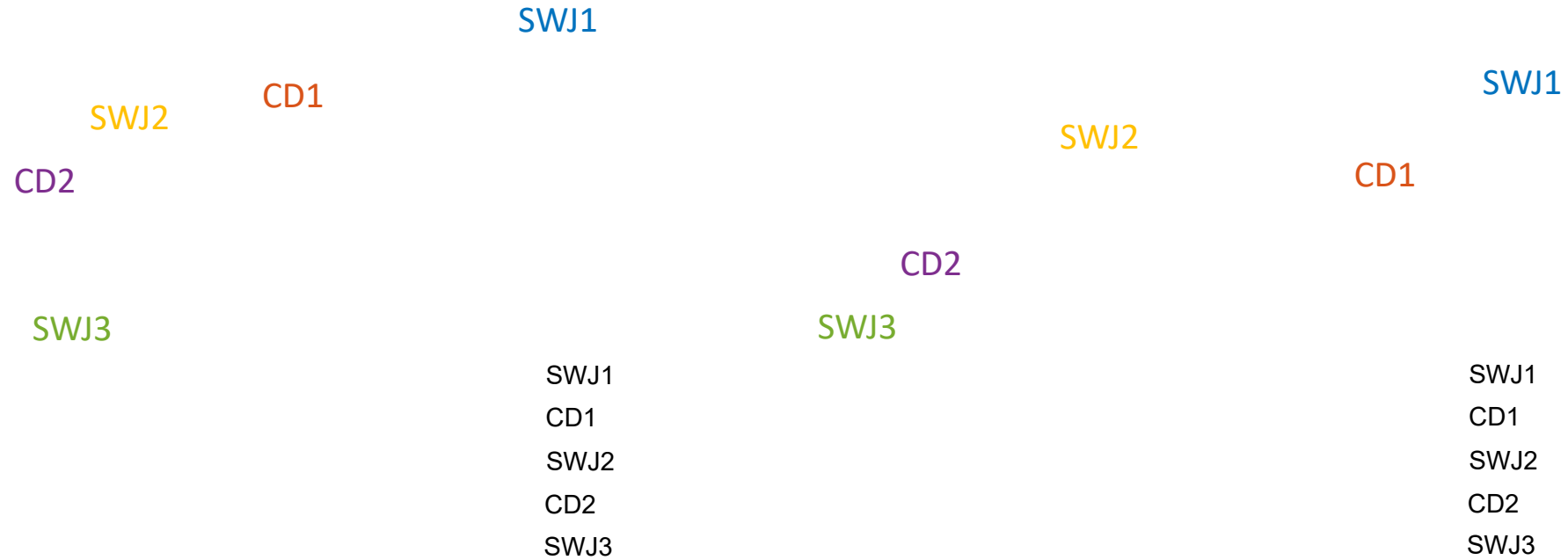
- NPR=1, flow separation at the aileron's TE
- AFC cases: Suction pressure increased: slat + main element
- Flow attached: CD1 at NPR=2 and CD2 at NPR=3
- Flow separation reduction: CD2 at NPR=2

AFC Evaluation Parameters



- Maximum improvement SWJ1
- SWJ2 and CD2 have similar performance improvements
- At NPR=2, CD1: CD1 has lower C_π than SWJ1

AFC Evaluation Parameters



- CDs more efficient than SWJs for this 3D flow field
- CD2 and SWJ2 have similar performance levels

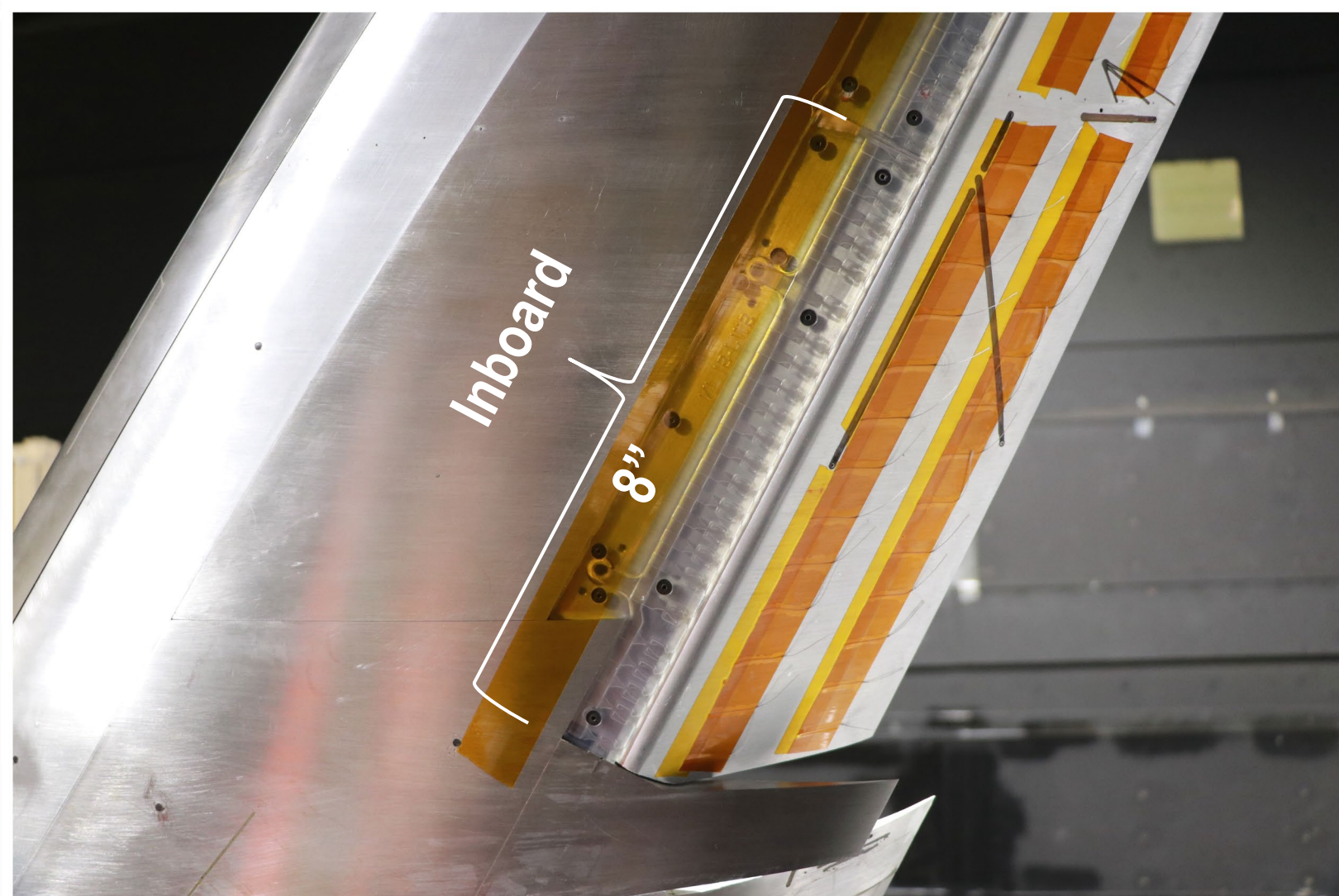
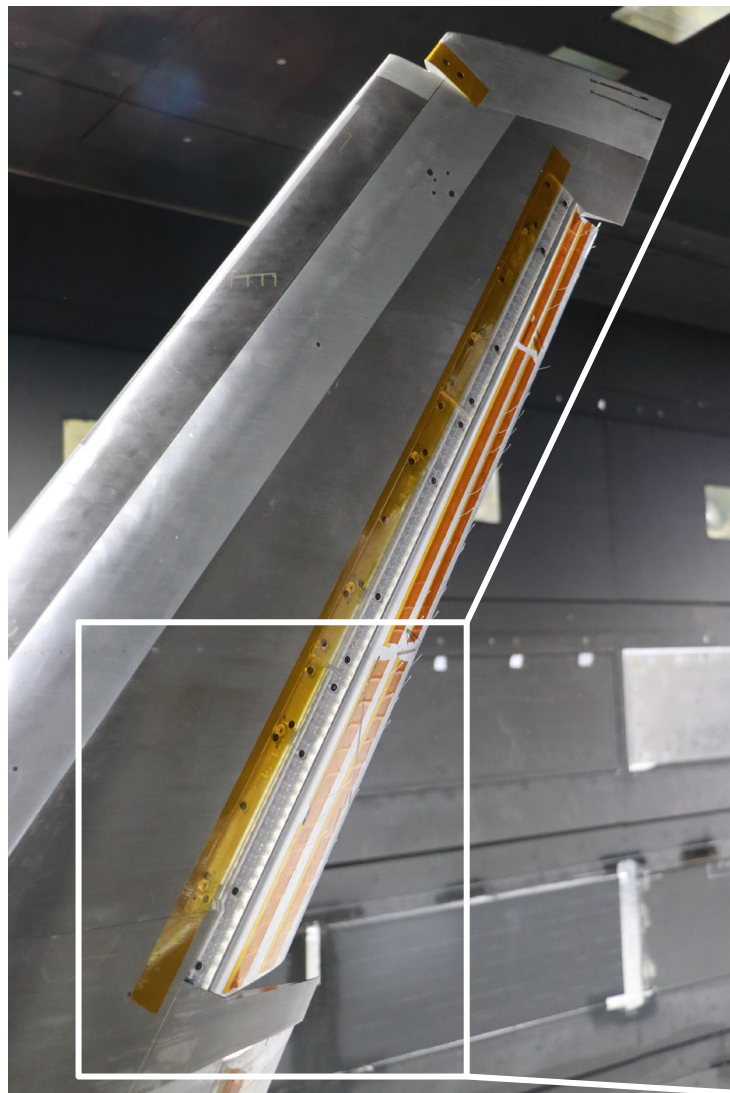
- An experimental investigation was conducted at the NASA Langley 14- by 22-Foot Subsonic Tunnel on the NASA 10% scale High-Lift Common Research Model in the takeoff configuration.
- AFC was applied to the aileron to enhance the L/D ratio for an aileron deflection angle of 16 degrees, HL-improved takeoff configuration.
- AFC performance was assessed using tuft visualization, steady surface pressure measurements, and force and moment data.
- All AFC cases resulted in increased C_L and reduced C_D , resulting in higher L/D ratios for both SWJs and CDs.
 - CDs demonstrated higher efficiency with similar aerodynamic performance compared to SWJs.
- Localized AFC was able to achieve drag reduction within a specific range of constant C_L .

- [illegible]

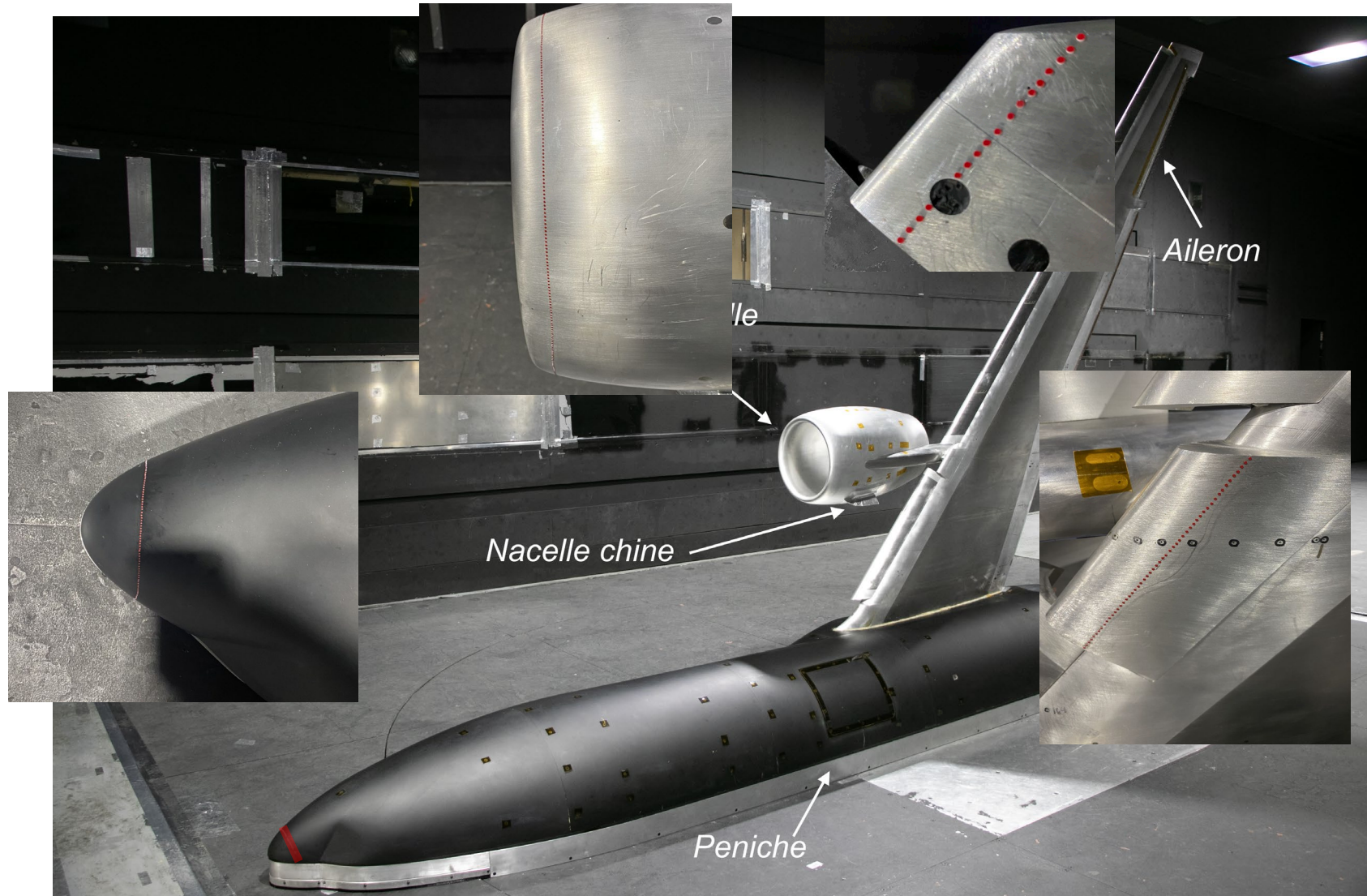
Questions



SWJ1 Actuators close-up



CRM-HL Trip Locations



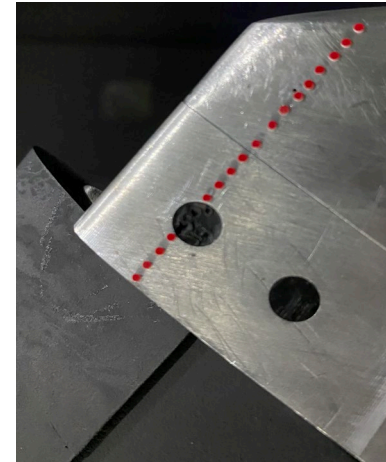
CRM-HL Trip Locations



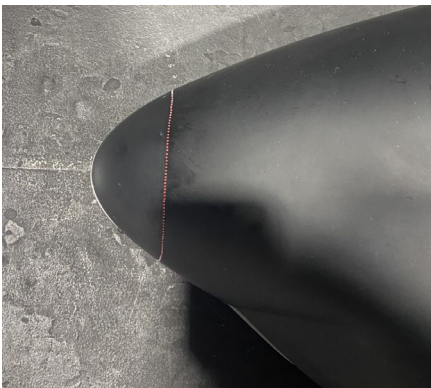
nacelle



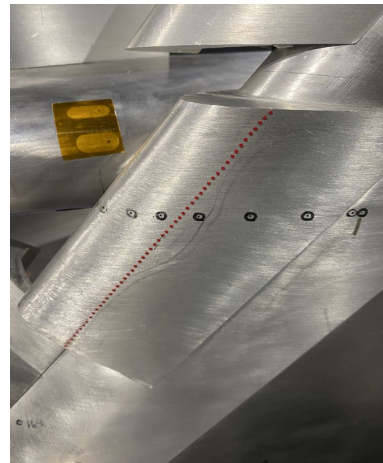
wing tip



fuselage nose



"slatless" WUSS



strake

